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Ash content, carbon and C/N ratio in paricá in function of NPK fertilization

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ABSTRACT

Fertilization in areas of forest plantations is needed to supplement plants´ nutritional needs until harvest. An experiment was performed to check the influence of fertilization on levels of ash, carbon and C/N relation in *Schizolobium amazonicum*. Soil liming was performed and fertilization occurred after 15 days of incubation. *S. amazonicum* seedlings were produced and submitted to fertilization with N, P and K: N = 0, 40, 80 and 120 kg ha^{-1}; P_2O_5 = 0, 50, 100 and 200 kg ha^{-1}; K_2O = 0, 50, 100 and 200 kg ha^{-1}. The plants were measured after 180 days. The seedlings of 20 treatments with the highest increase in height and diameter were transplanted to the field. Soil was fertilized and limestone was spread; seedlings were distributed into randomized blocks, with six replications. After 12 months, the plants were removed to determine ash, organic carbon, C/N relation contents. The ashes were submitted to digestion to determine nutrient concentrations. Fertilization influenced the levels of ash and organic carbon and C/N relation in *S. amazonicum*. Results indicate that the species has a potential for energy production.

Key words: Forest nutrition, inorganic compounds, *Schizolobium amazonicum*, vegetal charcoal.

INTRODUCTION

Schizolobium amazonicum Herb. (known as *paricá* in Brazil), is a native arboreal plant, commonly used in commercial planting, belongs to the Caesalpinaceae family and is characterized by fast growth, excellent adaptability and production capacity (Gazel Filho et al. 2007). It is one of the most planted native species in Mato Grosso, Brazil, in typical savannah soil. Fertilization is required since plants absorb nutrients in their development and during the biological cycle.

S. amazonicum timber may be used in beams of glued laminated timber, with satisfactory performance in resistance and elasticity module (Terezo and Szücz 2010). This quality of timber was tested by Vidaurre et al. (2012) who reported that its calorific energy might be compared to that of the *Eucalyptus* sp. timber, a species normally used for such energy ends. According to Pitre et al. (2010), the soil´s natural characteristics and fertilization are factors that affect timber quality. Changes in growth conditions caused by fertilizers

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are associated with alterations in timber quality with regard to their physical, chemical and anatomical characteristics.

In fact, fertilization may affect the final characteristics of timber and its final disposal as vegetal charcoal, furniture, paper, cellulose and others. It should be emphasized that chemical characteristics affect the timber´s physical qualities. Fertilization may improve translocation of minerals throughout the trunk in juvenile timber, whereas the chemical characteristics are the timber´s best quality indications after twelve months. Fertilization may also affect cellulose quality since it changes nutrient rates and the chemical factors used as parameters for timber quality. Sousa et al. (2010), Barbosa et al. (2014) and others have already shown the influence of fertilization on the timber´s chemical characteristics.

Ashes are compounds of inorganic matter inversely proportional to calorific power (Chaves et al. 2013). According to Neves et al. (2011), the high ash rate in the charcoal may accumulate impurities in the center of solidified metal wares with modifications in the physical, chemical and mechanical qualities of raw or cast iron. Timber is made up of ashes, also known as minerals, not merely in young and aged wood but also in the bark, with different concentrations in the two parts (Barcellos et al. 2005).

In their studies on the constitution of timber and the bark of eucalyptus clones, Andrade et al. (2011) concluded that the predominant nutrients in the timber were Ca, K, Mg and P. While Barreiros et al. (2007) concluded that cellulose, lignin and extractive and the timber´s calorific power rates were not modified although hemicelluloses and ash rates increased when the sludge of treated sewage was applied.

The final usage of timber produced in forest plantations will depend on the species, chemical and physical characteristics. Current research analyzes ash, organic carbon and C/N rates as indexes of the chemical characteristics of *S. amazonicum* timber submitted to different levels of NPK fertilization.

MATERIALS AND METHODS

Assay was performed at the greenhouse of the Faculdade de Agronomia e Zootecnia (FAAZ) of the Universidade Federal de Mato Grosso (UFMT) from seed-produced *S. amazonicum* seedlings which had been harvested from matrix trees in the municipality of Alta Floresta MT Brazil and produced in flowerbeds with sand.

Dystrophic red Oxisol soil used in current assay was collected in a region of native vegetation in the Instituto Federal de Mato Grosso, in São Vicente campus. It was previously dried, sieved and characterized chemically following methodology by Embrapa (1997), as shown in Table I.

Determining the soil´s chemical characterization, the soil was limed to raise the cation saturation to 50%, with 1.53 t ha^{-1} of limestone PRNT 100%, with 30.08% CaO and 21.1% MgO, calculated according to the following

TABLE I
Chemical analysis of the soil.

pH	H+Al	Al	Ca^{2+}	Mg^{2+}	K	P	SB	T(pH7.0)	t	V%	m%
$CaCl_2$		$cmol_c\ dm^{-3}$			mg dm^{-3}			$cmol_c\ dm^{-3}$			
4.39	4.22	1.03	1.0	0.50	13.56	13.9	1.53	5.75	2.56	26.5	40.2

pH in $CaCl_2$ – 1:2.5; H+Al – in calcium acetate; Al, Ca^{2+} and Mg^{2+} - in KCl 1N; P and K – in Mehlich; SB – sum of bases; T (pH 7.0) – capacity of cation exchange at pH 7.0; t effective – CTC effective; V% - cation saturation in %; m% - Al saturation in %.

equation: NC ($_{t/ha}$)= (V_E - V_A) T/100. Where NC = limestone requirement in tons per hectare; V_E = saturation per desired base in %; V_A = saturation per current base, in %; T = CTC at pH 7.0.

After a 15-day incubation period and seedlings with 15 cm high, the plastic bags (30x40 cm) were filled for the experiment. Seedlings underwent a 15-day adaptation period, after which the initial fertilization with different NPK levels was performed, with urea P.A. as N source; simple superphosphate as source of P_2O_5; potassium chloride P.A. as source of K_2O, with 0, 40, 80 and 120 kg ha^{-1} of N; 0, 50, 100 and 200 kg ha^{-1} of P_2O_5 and 0, 50, 100 and 200 kg ha^{-1} of K_2O. Factorial scheme 4x4x4 was designed in randomized blocks, with 10 repetitions.

The selected seedlings to be transplanted to the field of treatment were those in which the largest observed increase in height and diameter (Table II). Among the 64 treatments, the seedlings in 20 treatments were selected and, six plants in each treatment were transplanted into the field. The design consisted of randomized blocks with six repetitions, with similar fertilizations in the greenhouse, sources and doses, because it showed the same soil fertility conditions collected for growth analysis in nursery.

Prior to sowing, the 4x4-space holes were made into which limestone was placed directly. Soil was limed to raise the base saturation to 50%, with 1.53 t/ha, PRNT 100%, 30.08% CaO and 21.1% MgO. The NPK fertilization occurred after one week.

Seedlings were transplanted after 15 days to the limed holes and fertilized. The area under analysis lies on the Instituto Federal de Mato Grosso in São Vicente campus. Some ten years previous, the area had been used for pasture with typical savannah vegetation. Weeding and crowning occurred at the same time, over the 12-month of seedlings in the field, at intervals of 30 days.

The plants were removed and cut for leaves, stem and roots after 12 months. The later items were dried in an air buffer at 65ºC till constant weight on a 0.01 g precision semi-analytic balance. Dry matter was ground in a Wiley mill and sieved in 40 mesh sieves, collecting the material on 60 mesh sieves and

TABLE II
***S. amazonicum* seedlings produced in the greenhouse and planted in the field, according to treatment, with height and diameter at the moment of planting.**

Treatment	In field	N-P-K	Height (cm)	Diameter (mm)
1	B1T1	0-0-0	58	6.6
2	B1T10	0-100-50	82	7.3
3	B1T11	0-100-100	84	8.4
4	B1T13	0-200-0	93	9.2
5	B1T16	0-200-200	64	7.9
6	B1T15	0-200-100	88	9.1
7	B1T14	0-200-50	78	7.1
8	B2T13	40-200-0	92	7.9
9	B2T16	40-200-200	78	8.7
10	B2T15	40-200-100	92	9.2
11	B3T8	80-50-200	89	8.6
12	B3T2	80-0-50	90	10.3
13	B3T3	80-0-100	78	8.4
14	B3T4	80-0-200	83	8.3
15	B3T5	80-50-0	63	7.6
16	B3T7	80-50-100	80	9.5
17	B3T14	80-200-50	66	7.8
18	B3T15	80-200-100	80	12.1
19	B4T4	120-0-200	79	5.2
20	B4T7	120-50-100	90	7.7

analyses were performed thereby from this material. Ash rates were performed following methodology of the Associação Brasileira Técnica de Celulose e Papel - ABTCP 11/77 (1974), employing the previously ground and sieved material.

C/N ratio was determined by N concentrations by sulfuric digestion, following methodology by Malavolta et al. (1997), whereas C rate by carbon analyzer for solids HT 1300, Analytik Jena, at 1200ºC, with 2 g of ground and sieved material. Concentrations of macronutrients N, P, K, Ca and Mg and concentrations of micronutrient B in ashes were determined following Tedesco et al. (1995).

Assistat 7.6 Beta was employed for data processing and analysis. The statistical analysis was performed by analysis of variance and the compared multiple means were obtained by Scott-Knott method (p>0.05).

RESULTS AND DISCUSSION

Fertilization affected the concentrations of the timber´s chemical components and the C/N relation (Table III). The influence of fertilization for the stem section of the *S. amazonicum* plants was thus confirmed. Because according Swift et al. (1979) high lignin, cellulose and polyphenols are related to low decomposition rate, lower nutrient release and greater litter accumulation.

ASH RATE

According to Pereira et al. (2000), ashes between 0.5% and + 5% and depend on the species, quantity of bark and soil and sand in the timber. A good quality vegetal charcoal should have less than 3% ash. But, Rodrigues et al. (2009) disagree with the above authors and report that ash rates rarely should be over than 1% the dry weight of timber. However, Table III presents lower rates than 1% for ash rates in *S. amazonicum* plants´ stem.

Treatment 15 (80-50-0) had the lowest ash rate and equal in the other treatments. The above indicator is highly relevant since a high ash rate may corrode metal equipment. When timber is employed for the production of energy, the ash may

TABLE III

Rates (%) for ash, organic carbon (g kg^{-1}) and C/N ratio in the stem of *S. amazonicum* at different NPK levels.

Treatment	NPK	Ash rates	Carbon	C/N
T1	0-0-0	0.85 a	61.04 a	304.37 a
T2	0-100-50	0.84 a	60.38 a	342.22 a
T3	0-100-100	0.88 a	60.35 a	317.24 a
T4	0-200-0	0.89 a	56.57 a	360.08 a
T5	0-200-200	0.93 a	59.86 a	379.52 a
T6	0-200-100	0.83 a	60.17 a	369.85 a
T7	0-200-50	0.84 a	59.73 a	421.83 a
T8	40-200-0	0.87 a	57.98 a	364.35 a
T9	40-200-200	0.93 a	58.99 a	284.52 a
T10	40-200-100	0.87 a	61.42 a	361.04 a
T11	80-50-200	0.86 a	62.82 a	116.94 b
T12	80-0-50	0.82 a	61.62 a	142.74 b
T13	80-0-100	0.82 a	58.65 a	166.26 b
T14	80-0-200	0.85 a	58.22 a	246.70 b
T15	80-50-0	0.68 b	61.77 a	216.31 b
T16	80-50-100	0.92 a	59.06 a	317.28 a
T17	80-200-50	0.93 a	60.90 a	333.67 a
T18	80-200-100	0.90 a	59.36 a	190.98 b
T19	120-0-200	0.84 a	51.90 b	172.91 b
T20	120-50-100	0.90 a	51.64 b	128.56 b
CV (%)		8.90	5.77	35.87

Means followed by the same letter did not differ by Scott-Knott´s at 5% significance.

jeopardize the process by forming incrustations in the apparatus and tubes. Results show *S. amazonicum*´s capacity in energy production, similar the reported by Vidaurre (2010) for five-year-old *S. amazonicum* timber (mean 0.82). According to the author, ash rate did not show any decreasing trend in proportion to age increase. However, results were relatively high and negative for most of the chemical processes in timber conversion. They were, however, similar to those reported by Neves et al. (2011) for *Eucalyptus* sp.; by Medeiros Neto et al. (2012) for *Handroanthus impetiginosus* and; by Paes et al. (2013) for *Tabebuia aurea*.

Neves et al. (2011) reported ash rates between 0.07 and 1%, are rather low and do not make difficult the species´s energy usage. In fact, this was what occurred in all treatments tested in current assay. But, Cunha et al. (1989) suggested a variation of timber ash rates between 0.03% and 3.00% in the case of the Amazon species.

Several rates were reported within this range, largely lower than 3%, results registered by Cintra (2009) in savannah timber, such as *Anadenanthera falcata*, *Enterolobium contortisiliquum* and *Zanthoxylum* sp. and by Vidaurre (2010) in *S. amazonicum* timber. However, rates during the initial phase of *S. amazonicum* plants submitted to fertilization were lower.

Several authors show the co-relationship between the ash rates and timber resistance. Paes et al. (2013) reported that *Anadenanthera colubrina* had the most resistant timber and *Eucalyptus camaldulensis* the least resistant to thermites, with regard to heartwood and sapwood. Trugilho et al. (2001) demonstrated that there was a great relationship (0.97) between the estimated masses of insoluble and total lignin, and those of vegetal charcoal in the dry matter. And, Medeiros Neto et al. (2012) registered that high ash rates were inversely proportional to lignin and calorific power rates in *Poincianella pyramidalis* and *Handroanthus impetiginosus* timber.

Preliminary results on ash rates in *S. amazonicum* plants indicated that the species is capable to be used as energy production.

CARBON RATE

Data on C rates during the initial period (one year old) may provide important information in decision-taking and in the proper planning of forest populations. In fact, C rates vary according to species and in the different plant components (Behling et al. 2014).

C rates were lower in treatments 19 (120-0-50) and 20 (120-50-100), with a 15% decrease for the two treatments when compared to the control treatment. However, rates were high in all treatments, varying between 51.64 and 62.82, perhaps due to the age of the species, since it is a material in the timber´s formation phase. However, rates were similar to those given by Sette Junior et al. (2006) and Dallagnol et al. (2011).

Vidaurre (2010) reported lower C rates in *S. amazonicum* than those in the eucalyptus planted in Brazil. According to the same author, since C rates did not decrease with a rise in tree age, current research revealed higher rates, perhaps related to fertilization.

Behling et al. (2014) analyzed plants of *Acacia mearnsii* Wild, *Eucalyptus grandis* W. Hill ex-Maiden and *Mimosa scabrella* Benth. and showed that, even in a young one-year-old forest, rates were similar to those by Higuchi and Carvalho Junior (1994) in their studies on C phytomass and contents of the Amazon tree species, within the 46 - 52% concentration limits in tropical forests. However, rates for *S. amazonicum* plants are slightly higher, probably due to plants´ age or the fertilization.

However, high C rates may be highly advantageous. Sturion et al. (1988) recommended *Eucalyptus viminalis* as good quality timber producing species for the production of charcoal, due to low ash rates (less than 2.6%) and high C rates. In the production of charcoal, C is converted into fixed C, the main cause of stored energy. C is totally consumed in direct burning and it is expected that timber with the highest C rates also have the highest thermal capacity due to a greater energy release (Santos et al. 2011). Data corroborate the use of young *S. amazonicum* timber as fuel. Sette Junior et al. (2006) attributed high C rates to such variables as site conditions, genetic matter, management type and the C rate quantification method and its interactions.

However, C rates in *S. amazonicum* indicated the specie to energy production. What depends on the fertilization.

C/N RATIO

If the C/N ratio affect directly the degradation time of the vegetal material, it might indicate the lignin rate in the timber, or rather, its difficulty in fungus-caused degradation and the species combustion power, which might be increased by fertilization.

Further, the chemical composition of timber can affect the physical and chemical quality of the charcoal. The higher lignin rate in the timber, the higher was the energetic potential of the charcoal and a higher gravimetric yielded at the end of the carbonization process. It's because the high thermal resistance of lignin, the primary compound, with the highest C rate in its composition (Pimenta and Barcellos 2000).

C/N ratio was lower in treatments 11 (80-50-200), 12 (80-0-50), 13 (80-0-100), 14 (80-0-200), 15 (80-50-0), 18 (80-200-100), 19 (120-0-200) and 20 (120-50-100). Variations occurred between 116.94 and 421.83. However, taking into account the recommendation of Moreira and Siqueira (2002), C/N rates higher than 20 indicate immobilization as the dominant process, it may be verified that the material produced is richer in COT (Total carbon organic) than in NT (Total nitrogen). According to Santos et al. (2013), it is generally expected that timber with high C rates have a positive relationship, coupled to a greater thermal resistance and, consequently, more durable energy provision.

Moulin et al. (2011) reported that C/N varied between 133.95 and 627.02, and indicated that the material was more suitable for energy production. In this case, the species from the fertilization of treatments 11 (80-50-200), 12 (80-0-50), 13 (80-0-100), 18 (80-200-100), 19 (120-0-200) and 20 (120-50-100) were more indicated for combustion.

NUTRIENTS IN *Schizolobium amazonicum* ASHES

Fertilization affected N, P, K, Ca and B concentrations in *S. amazonicum* ashes (Table IV). P, Ca, B and also K in certain cases are the main inorganic elements in the stem of *S. amazonicum* plants.

Low concentrations of N are preferred. Because, S and N contribute only slightly to energy release from fuel besides causing pollution to the environment and the formation of acid rain after their release into the atmosphere during combustion (Bilgen and Kaygusuz 2008). It is highly expected that in this case the biomass has low N rates due to environmental pollution as toxic nitrogen oxides after combustion (Kumar et al. 2010). The treatment 19 (120-0-200) presents N concentrations 77% higher than the control. This would not be the best treatment since it is not the primordial one for energy production and would cause a higher pollution level. Least rates were reported in fertilizations with 0-200-200 and 40-200-100, requiring phosphated fertilization. As a rule, results obtained were similar to those by Andrade et al. (2011) and by Santos et al. (2013).

Highest P concentrations occurred in fertilization 0-200-200 or treatment 5, 86% higher than those control, or rather in the highest P dose without any N fertilization. Andrade et al. (2011) and Timm et al. (2003) also reported high P rates

TABLE IV
Macronutrients (in g kg^{-1}) and B (in mg kg^{-1}) in the ash of the *S. amazonicum* stem at different NPK levels.

Treat.	NPK	N	P	K	Ca	Mg	B
T1	0-0-0	1.30 d	3.70 c	0.50 i	2.25 b	0.60 a	28.55 b
T2	0-100-50	0.70 d	1.15 c	0.00 j	1.00 c	0.35 a	6.67 c
T3	0-100-100	1.32 d	10.07 b	4.30 f	3.75 a	0.55 a	14.65 c
T4	0-200-0	1.47 d	8.55 b	2.35 h	3.82 a	0.45 a	11.85 c
T5	0-200-200	0.70 d	26.95 a	21.00 a	5.15 a	0.70 a	9.70 c
T6	0-200-100	1.32 d	5.30 c	1.20 i	2.80 b	0.50 a	7.72 c
T7	0-200-50	1.27 d	3.77 c	0.77 i	2.22 b	0.40 a	9.97 c
T8	40-200-0	1.37 d	4.15 c	3.00 g	2.87 b	0.65 a	5.75 c
T9	40-200-200	1.37 d	8.35 b	19.65 b	4.47 a	0.45 a	5.30 c
T10	40-200-100	0.77 d	4.92 c	6.10 e	3.57 a	0.25 a	24.50 b
T11	80-50-200	4.60 b	2.90 c	2.15 h	3.62 a	0.70 a	9.72 c
T12	80-0-50	1.37 d	1.35 c	0.05 j	1.55 c	0.50 a	12.60 c
T13	80-0-100	0.95 d	0.42 c	0.00 j	0.85 c	0.70 a	13.07 c
T14	80-0-200	1.47 d	1.50 c	0.40 j	1.65 c	0.35 a	10.15 c
T15	80-50-0	2.00 c	2.55 c	0.90 i	2.22 b	0.50 a	11.92 c
T16	80-50-100	1.35 d	1.52 c	0.65 i	1.85 c	0.30 a	11.65 c
T17	80-200-50	1.95 c	11.12 b	14.90 c	3.70 a	0.50 a	10.52 c
T18	80-200-100	2.15 c	2.90 c	9.55 d	2.52 b	0.65 a	13.10 c
T19	120-0-200	5.70 a	3.47 c	4.15 f	3.67 a	0.65 a	15.10 c
T20	120-50-100	4.20 b	3.35 c	6.60 e	3.80 a	0.30 a	50.90 a
CV (%)		28.74	50.57	7.81	32.88	62.98	47.84

Means followed by the same letter did not differ by Scott-Knott´s test at 5% significance.

in timber ashes, mainly due to an increase in the element´s solubility (Gómez-Rey et al. 2010), promoted by the limestone and fertilization.

The highest K concentrations were observed in fertilization 0-200-200 (treatment 5), similar to what occurred in P in the highest dose, which did not require N fertilization. In fact, it was 97.6% higher compared to treatment 0-0-0 (control). Andrade et al. (2011) verified high concentrations of K in the timber´s ashes since, too.

The highest Ca concentrations were reported in treatments 3 (0-100-100), 4 (0-200-0), 5 (0-200-200), 9 (40-200-200), 10 (40-200-100), 11 (80-50-200), 17 (80-200-50), 19 (120-0-200) and 20 (120-50-100), with rates 40%, 41%, 56%, 49.6%, 37%, 37.8%, 39%, 38.7% and 40.8%, respectively, higher when compared to control (0-0-0). Similar rates were obtained by Andrade et al. (2011) in *Eucalyptus* sp. Therefore, timber ashes may be used as organic fertilization (Severino et al. 2006). However, there was no significant difference in Mg concentrations due to different N, P and K doses.

The highest B concentrations were obtained in treatment 20 (120-50-100), 44% higher than those in control. In other words in the highest N dose and in the lowest P dose, thus requiring macronutrients´ interactivity.

CONCLUSIONS

Fertilization affected C/N rates in *S. amazonicum* plants. The ash content and organic carbon show and increasing trend with NPK level in the soil.

Preliminary results of ashes content, carbon organic content and C/N ratio heightened the use of *S. amazonicum* for the production of energy. P, Ca and B were the predominant inorganic elements in *S. amazonicum* ashes.

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